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Description

~~Hydraulic Transformer~~

The invention relates to a hydraulic transformer in accordance with the preamble of claim 1.

A hydraulic transformer is a unit wherein an energy flow $Q_1 \times p_1$ is transformed into an energy flow $Q_2 \times p_2$ through hydraulic coupling of a hydrostatic motor and a pump. In the process, only the amount of hydraulic energy required for driving a consumer that is connected to the pump is withdrawn from an existing pressure supply. Such hydraulic transformers may be designed as radial piston engines, axial piston engines, or in accordance with other kinematic function principles, e.g., as vane-cell machines.

US 3,188,963 discloses a hydraulic transformer having the form of a swashplate motor, wherein displacers guided in a rotatable cylinder are supported on a stationary swash plate. The angle of the swash plate determines the piston stroke of the displacers. Pressure medium supply and discharge are performed with the aid of a control disc having four control kidneys, wherein the respective pairs of control kidneys are associated with the motor and the pump.

In US 3,079,864 a hydraulic transformer in vane-cell construction is disclosed. In this solution, a multiplicity of displacers translatable in a radial direction are mounted in a rotor and biased against a cam ring. Pressure medium supply and discharge are performed, similar to the above described solution, with the aid of a control disc arranged on the front end side.

From WO 97/31185 A1 and from the reference, "*Ein neuer alter Bekannter - der Hydrotransformator*" [A new old acquaintance: the hydraulic transformer], Siegfried Rotthäuser, Peter Achten; O+P "Ölhydraulik and Pneumatik" 42 (1998) No. 6; p. 374 et seq., the so-called INNAS hydraulic transformer is known, wherein the transformation ratio, i.e. the ratio between the supply pressure and the pressure for supplying the consumer, is variable. To this end, a control disc is provided with three control kidneys, the relative position of which to the dead center positions of the displacers is variable by rotation relative to the swash plate of an axial piston machine.

From DE 100 252 48.6, a further development of the hydraulic transformer disclosed in WO 97/31185 A1 is known. In this solution, the pressure medium ports (supply port, work port, tank port) open in a radial direction into the rotatable control means, so that the forces acting in an axial direction are reduced.

In hydraulic transformers of this design, the displacer chambers are inherently also shifted outside of the dead center positions, wherein this shifting may take place at arbitrary piston velocities. Shifting takes place within a substantially smaller rotational angle interval in comparison with pumps and motors, so that comparatively high pressure gradients may occur, which may lead to excessively high mechanical strains on the hydraulic transformer and high noise emission.

Besides these high pressure gradients, particularly pressure adaptation during shifting is very difficult to implement in practice. In the ideal case, the pressure should rise or drop linearly to the subsequent pressure level during the entire rotational angle interval. It was

found, however, that such a shifting property cannot be realized across the entire operating range of the transformer. The rigid commutation geometry may lead to cavitations and pressure peaks in the commutation ranges, so that the above described noise emissions and the mechanical strain on the hydraulic transformer are increased further.

Before this background, the invention is based on the object of providing a hydraulic transformer wherein the load is reduced by pressure gradients in the commutation range.

This object is achieved through a hydraulic transformer having the features of claim 1.

In accordance with the invention, the hydraulic transformer is provided with a multiplicity of displacers each guided in a displacer chamber and capable of being connected through commutation means including a pressure port, a consumer port, or a tank port, the relative position of the commutation means being variable relative to the dead center positions of the displacers. In accordance with the invention, the oil volume of the displacer chamber to be shifted is increased during the commutation phase. This is achieved in particular in that in this commutation phase, the respective displacer volume is connected with a commutation chamber. As a result of these increases in the oil volume, the pressure gradients, pressure peaks, and noise emissions are reduced considerably in the commutation phase.

In a particularly preferred embodiment, the control means include three control recesses distributed at the periphery, with the commutation chambers opening into respective ranges between two adjacent control recesses.

Here it is particularly preferred if these control recesses have an approximate kidney shape, and the commutation chambers each open into one of the kidney separation webs.

In a preferred embodiment, the control kidneys and through bores of the commutation chambers are formed in a control disc of the control means.

In a preferred manner, the commutation means have next to the control disc a base body in which a part of the commutation chamber is formed next to the through bores of the control disc.

It is particularly advantageous if the volume of each commutation chamber is greater or at least equal to the displacement volume of a displacer.

The volume of the commutation chamber should, however, preferably be less than five times the displacement volume. This range may, however, vary in accordance with system pressure, switching frequency, and geometry of the control bores.

The hydraulic transformer of the invention preferably has the form of an axial piston bent-axis unit. As was already mentioned at the outset, the invention may also be applied in other kinematic functional principles for hydraulic transformers.

Further advantageous developments of the invention are subject matters of the remaining subclaims.

In the following, a preferred practical example of the invention shall be explained in more detail by referring to schematic drawings, wherein:

Fig. 1 is a three-dimensional representation of a hydraulic transformer in bent-axis design;

Fig. 2 is a front view of a control member of the hydraulic transformer of Fig. 1;

Fig. 3 is a three-dimensional representation of the control member of Fig. 2; and

Fig. 4 is a longitudinal sectional view of the control member of Figs. 2 and 3.

Fig. 1 shows a three-dimensional schematic representation of a hydraulic transformer 1 executed in bent-axis design. In principle, a like hydraulic transformer 1 may be represented as a combination of a hydrostatic motor and a hydraulic pump mechanically coupled to each other. In accordance with the prior art described at the outset, hydraulic transformers may be realized through variable displacer units, with axial piston machines or vane cell machines preferably being used. Fundamentally it is, however, possible to employ any displacer unit where the displacers may be controlled such that they may successively be taken into operative connection with three pressure levels: the supply pressure, the tank pressure, and the consumer pressure (work pressure).

The hydraulic transformer 1 in accordance with Fig. 1 includes an angled housing 2 in which displacers guided inside a cylinder drum, a drive flange, and a drive shaft are arranged. To the angled housing 2 a control housing 4

is attached which is closed by a cap 5. Supply and discharge of the pressure medium to and from the cylinder chambers is effected through a control member 12 accommodated in the control housing 4 which may be adjusted to vary the transmission ratio between pump and motor. The commutation means may be adjusted in relation to the dead center positions of the displacers with the aid of adjusting means, such as with the aid of an electric motor 6 or any other suitable drive mechanism, e.g., a gear drive.

On the angled housing 2 and on the cap 5 a work port B, a tank port T, and a supply port A are provided. These ports may be executed as axial or radial ports.

The construction of the bent-axis unit including the displacers is sufficiently known from the prior art. In this regard, reference is made, e.g., to patent application DE 100 252 48, so that a detailed description of the bent-axis unit may be omitted.

The control member 12 of Figs. 2 to 4 is rotatably mounted in the control housing 4 and includes at its outer periphery a flange 14 for axial contact with a gear (not shown). By means of this gear it is possible to adjust the control member 12 in relation to the dead center positions of the displacers. The control member 12 hat on its end-face side (view of Fig. 2) a control disc 16 which sealingly contacts the cylinder drum rotatably mounted in the angled housing 2. Inside this cylinder drum, the displacers are guided which are translatable in an axial direction and supported on a bent axis. Three control kidneys 18, 20, 22 distributed on the periphery extend through the control disc 16. Between two respective adjacent control kidneys there remains a

kidney separation web 25 into which an axial blind bore 23, 27 or 29 opens.

As is particularly evident from the three-dimensional representation of the control member 12 in Figur 3, the control disc 16 is part of a base body 24, at the outer periphery of which the flange 14 is formed. In the base body 24, connection passages 26, 28, 30 are formed whereby the control kidneys 18, 20 and 22, respectively, are connected with the associated pressure medium ports. In the represented practical example, the control kidney 18 is connected via the connection passage 26 and radially merging passages 32 with the tank port T, control kidney 20 is connected via the connection passage 28 and an oblique passage 36 extending obliquely to the axis 34 of the control member 12 with the consumer or work port B, and control kidney 22 is connected via three bores 38 extending in parallel with the axis with the supply port A. I.e., depending on their position relative to the control kidneys 18, 20, 22, the displacers may be subjected to the pressure at the tank port T, at the work port B, or at the supply port A. The width of the kidney separation webs 25 is selected such that a displacer volume may be covered by the kidney separation web 25 in the commutation phase between two adjacent control kidneys. In conventional solutions, these kidney separation webs are closed, so that in the commutation phase a complete coverage of the displacer chamber ensues. In accordance with the invention, in the commutation phase the displacer chambers located in the range of the kidney separation webs 25 are connected with dead spaces 40, 42 and 44 represented in Fig. 3 via the blind bores 23, 27 and 29. These have the form of axial and radial or oblique bore sections in the base body 24 and are represented externally of the control member 12 in Fig. 3 for the sake of clarity. The geometries of the

above described connection passages 26, 28, 30 and of dead spaces 40, 42, 44 separated therefrom depend on the geometry of the base body 24. In the represented practical example, the dead space 44 is essentially formed by a centrally arranged, axially extending cavity that is connected with the blind bore 29 through a transverse bore. The two commutation chambers 40 and 42 are formed by radially offset bore sections substantially extending in the axial direction and interconnected by respective oblique or radial bores. The dead space 44 is closed against the control disc 16 by a screw plug 45. The axially extending bores of the two other dead spaces are introduced into the end face side of the control member 12 facing away from the control disc 16 and are closed by screw plugs 46. Likewise, the radial bores of the dead spaces are closed externally by screw plug. The volume of the commutation chambers, which also encompasses the volume of the blind bores 23, 27, 29, in each case corresponds to at least the displacement volume of one displacer and should not exceed five times the displacement volume of one displacer in order to minimize compression/decompression losses.

The displacers accommodated in the rotating cylinder drum are in the course of their rotary movement successively connected with the three control kidneys 18, 20 and 22 and subjected to the corresponding pressure. In the commutation phase the respective displacer volume is connected through one of the three through bores 23, 27 and 29 with the associated dead space 40, 42 or 44, respectively, so that in practice, the oil volume of the associated displacer chamber is increased by the volume of the dead space. Owing to the resulting smooth shiftitng, the above described strains and noise emissions are reduced considerably, and thus the effectivity of the hydraulic transformer is improved in

comparison with conventional solutions. First test runs with the hydraulic transformer of the invention confirm its superiority over the known solutions.

As was already mentioned, the shape of the cavities inside the base body 24 is of minor importance. What is essential is that the volumes of the dead spaces effective in the commutation zones are dimensioned in accordance with system pressure, switching frequency and geometry of the through bores, such that the rigidity of the "oil spring" is reduced in the commutation phase.

A hydraulic transformer includes a multiplicity of displacers each guided in a displacer chamber. Pressure medium supply and discharge to and from the displacer chambers is controlled through the intermediary of control means provided with control recesses. The effective position of the control recesses in relation to the dead center positions of the displacers is variable, with each displacer volume being adapted to be connected with a dead space in a commutation phase upon transition between two adjacent control recesses.

List of Reference Symbols

1	hydraulic transformer
2	angled housing
4	commutation means
6	handle
10	control housing
12	control member
14	flange
16	control disc
18	control kidneys
20	control kidneys
22	control kidneys
23	through bore
24	base body
25	kidney separation web
26	connection passage
27	through bore
28	connection passage
29	through bore
30	connection passage
32	passages
34	axis
36	oblique passage
38	bores
40	commutation chamber
42	commutation chamber
44	commutation chamber
45	screw plug
46	screw plug

Abstract

A hydraulic transformer includes a multiplicity of displacers each guided in a displacer chamber. Pressure medium supply and discharge to and from the displacer chambers is controlled through the intermediary of control means provided with control recesses. The effective position of the control recesses in relation to the dead center positions of the displacers is variable, with each displacer volume being adapted to be connected with a dead space in a commutation phase upon transition between two adjacent control recesses.